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SATELLITE X-RAY TEST FACILITY INSTRUMENTATION STUDY

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31 October 1976

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    The proposed DNA Satellite X-ray Test Facility (SXTF) will require an instrumentation system integration which will be a significant part of the overall facility development. This report is a preliminary survey of the instrumentation system with conceptual designs, a division of instrumentation into tasks and subtasks, and a definition of approach for each with a review of those areas in which additional research and development is required. A summary of findings is included.

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CONTENTS

1. INTRODUCTION

The proposed Defense Nuclear Agency (DNA) satellite x-ray test facility (SXTF) will require an instrumentation system integration which will be a significant part of the overall facility development and construction.

Prior to facility construction, a wide variety of inputs from the instrumentation design will have to be incorporated into the building design. These include grounding systems and conduit which must be buried in the concrete floor, equipment room layouts and sizing, air conditioning, filtering, and power requirements.

This report is a preliminary survey of the instrumentation system with conceptual designs, a division of instrumentation into tasks and subtasks, and a definition of the instrumentation approach for each task with a review of those areas in which additional research and development is required. Section 2 outlines some requirements and conceptual designs for the overall instrumentation facilities. Specific hardware and software concepts are discussed in Section 3, which includes a survey of the individual subsystems of the facility. A software design philosophy and dosimetry considerations are also reviewed in Section 3. Initial cost estimates, as well as program scheduling, are presented in Sections 4 and 5, respectively. Information gathered from visits to satellite manufacturers is found in Appendix A. Appendix B contains a list of documents which characterize and specify electromagnetic shielded enclosures.

2. INSTRUMENTATION FACILITIES

2.1 INSTRUMENTATION ROOMS

There are three general categories of instrumentation: facility data acquisition and control, experimental data acquisition and control, and user-furnished instrumentation. These are abbreviated as control, data, and user systems.

Control is the acquisition and control of all facility-provided functions necessary to perform a satellite-generated electromagnetic pulse (SGEMP) test, excluding instrumentation of the test module or satellite.

Data or data acquisition is the instrumentation needed to make SGEMP measurements on the test module or satellite.

User or user instrumentation is the test module manufacturer's system of test sets and controls, which are support and diagnostics for the satellite.

Each function (control, data, and user) requires an electromagnetic, radio-frequency interference (RFI), tight enclosure or screen room appropriately located for access to the photon sources, vacuum chamber, and clean rooms. Figure 1 is a preliminary layout of the instrumentation rooms as fitted to a vacuum chamber 75 feet in diameter.

Instrumentation and control systems operating in a high-current, high-voltage, fast-pulse environment require carefully planned and designed enclosures and operating conditions due to the electromagnetic noise and to the extreme sensitivity of the data acquisition systems. Determination of detailed specifications for RFI protection, screen rooms, and grounding systems requires calculations based upon the complete electrical characteristic of the photon sources (and power supply). Since these parameters are not yet known, this report presents general considerations and conceptual designs based upon experience at the CASINO and AURORA facilities. Some details may require

75' DIA.

VACUUM
CHAMBER

PHOTON
SOURCES

PREP.
AREA

6'

6'

CONTROL
ROOM

21' X 33'

USER
DATA

21' X 33'

RFI
ENCLOSURE

6'

CONTROL
DATA

21' X 24'

EXPERIMENTAL
DATA

21' X 39'

SCALE
1/2" = 10'

OFFICE SPACE

20' X 95'
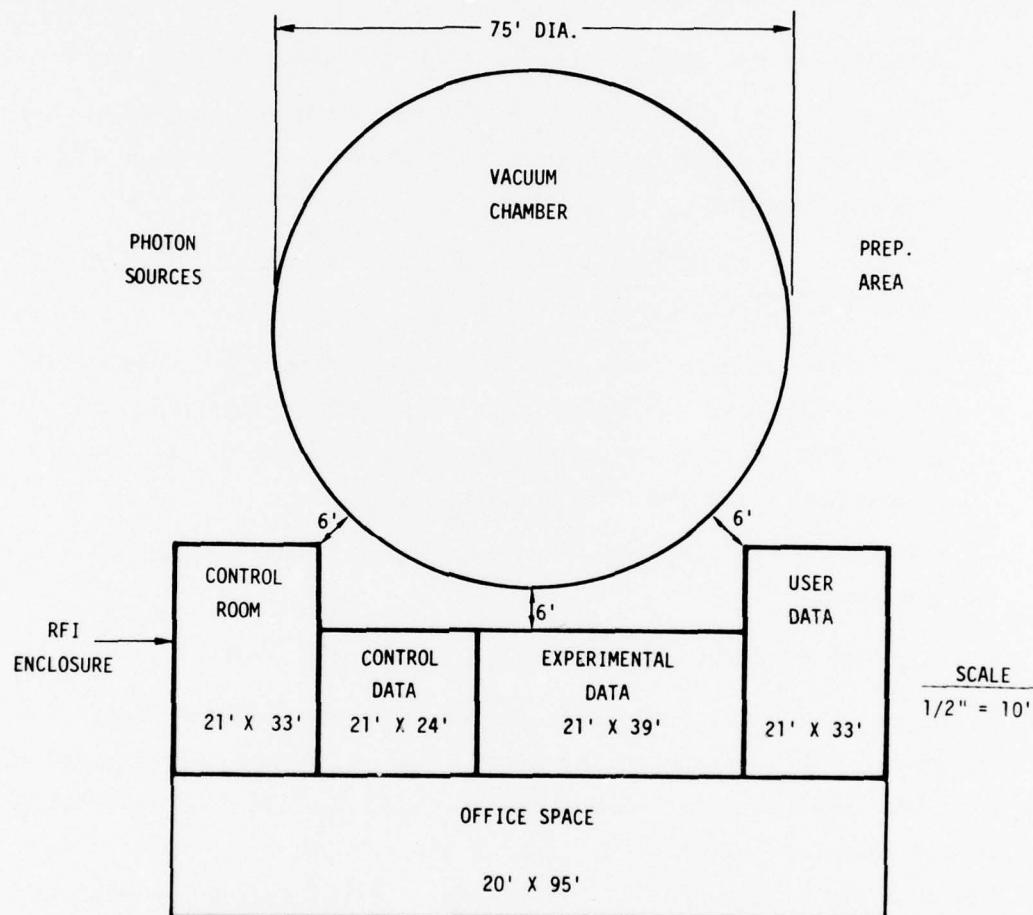
RT-14553

Figure 1. Instrumentation room floor plan

modification when the source characteristics become known and the appropriate calculations are performed.

Several general rules are applied to ensure satisfactory data acquisition and control. These include the following:

1. Install all equipment in RFI enclosures, i.e., screen rooms.

2. Filter all electronic lines to and from each RFI enclosure where unshielded and unterminated signals within the enclosure might broadcast noise.

3. Tie screen rooms to ground planes, with cabling in conduits closely coupled to ground.

4. Within each screen room provide low-noise lighting, filtered 24-hour air-conditioning systems with humidity control, and forced-air cooling for equipment racks and controls with positive air pressure to uncontrolled areas.

5. Transform, isolate, and filter a.c. power lines to each RFI enclosure.

6. For high-frequency data, keep the data paths short.

In Figure 1, the RFI enclosures are actually one enclosure with four RFI partitions with interconnecting doors. Cables between partitioned sections are fed through filter panels and bulkhead feedthroughs, so that each section may have RFI integrity by closing the necessary doors.

The attached office space is of conventional design and is used to reduce the cost and size of the RFI enclosure, to provide immediate working areas near the instrumentation, and to buffer the instrumentation from the dirt and dust of the building machinery and maintenance areas.

The partitioned sections each contain an elevated "computer room" and antistatic floor with removable panels for cable installations and access. Under this same floor are air-conditioning ducts and dampers for selectively cooling high-power consumption instrumentation.

The control or operations room is actually divided into two sections. One is a 600-square-foot area for the operating controls of the two photon

sources. The second room contains a computing system which records and monitors the operating parameters and outputs of the photon sources. These parameters will include charge voltage, pulse-line voltage, radiation output magnitude and waveform, and machine diagnostic sensor. This system will be similar to the data acquisition instrumentation, except for its dedication to daily operations, analysis, and information. The second room of approximately 400 square feet is partitioned from the control console room to prevent interference from the uncontrolled electromechanical systems in the control console, which would be furnished by the photon-source manufacturer.

The approximately 800-square-foot data acquisition room will contain a transient data acquisition system using high-speed digitizers in a computer-controlled system. Signal sources will be probes coupled to satellites by radiation-hardened fiber-optic data links. The fibers will be brought through the skin of the vacuum chamber and the RFI enclosure to the transient digitizers.

The data instrumentation system and the control instrumentation system may be coupled to provide *backup, redundance, and* data and peripheral sharing.

The user instrumentation room will be a semivacant room for user operations such as telemetry control and reception, and active systems monitoring. It should contain 400 to 600 square feet.

Both the data and user rooms will be provided with precise timing signals for synchronization of recording and measurement systems. In addition, audio and video communications will be provided as required.

Suggested layouts of the four rooms are shown in Figures 2, 3, and 4.

2.2 GROUND SYSTEMS

Ideally, the RFI enclosure would be tied to a low impedance system ground or ground plane at one point, and all cables into the RFI enclosure would penetrate at that point. An alternate conservative ground scheme is to isolate the RFI enclosure on insulating pads, and to bury a large ground plane in the concrete under all photon sources, the test chamber, and RFI enclosures.

In Figure 5, a ground plane of copper straps, copper screen, and earthing rods is shown installed in the cement with tie straps brought out of the cement for tie points.

RT-14554   CONTROL ROOM
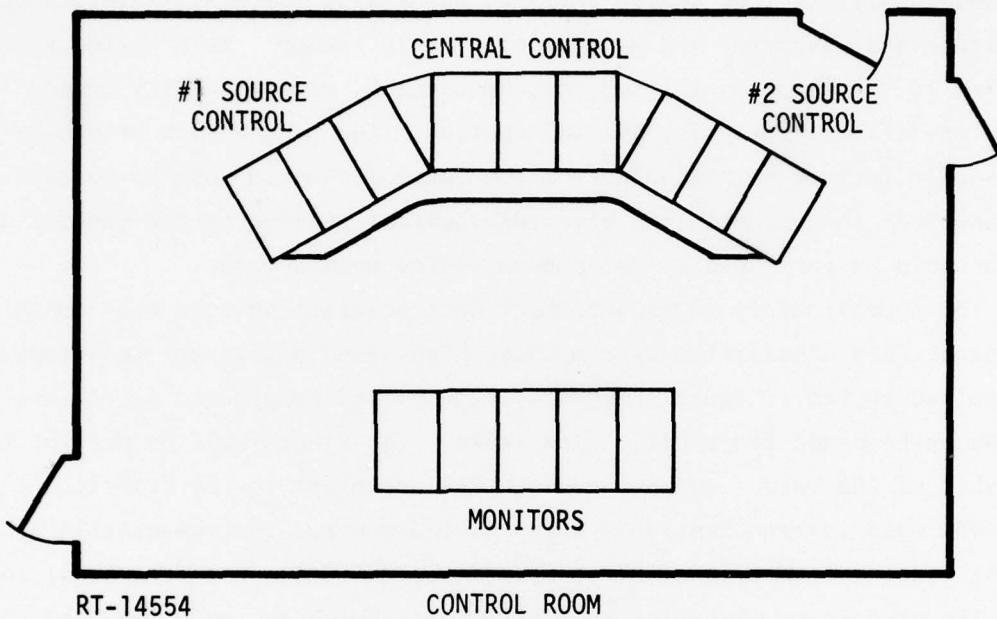
- PHOTON SOURCES OPERATING CONSOLE

- BACKSCATTER CONTROL

- TIMING AND FIRING SOURCE

- SAFETY INTERLOCKS

- AUDIO/VIDEO

- SOLAR SOURCE AND COLD DECK

SCALE

1.5 inches = 10 feet

NOTE: Racks 24 inches wide, 36 inches deep

Figure 2. Control room

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DATA ACQUISITION

TRANSIENT DIGITIZERS

COMPUTER

TABLE
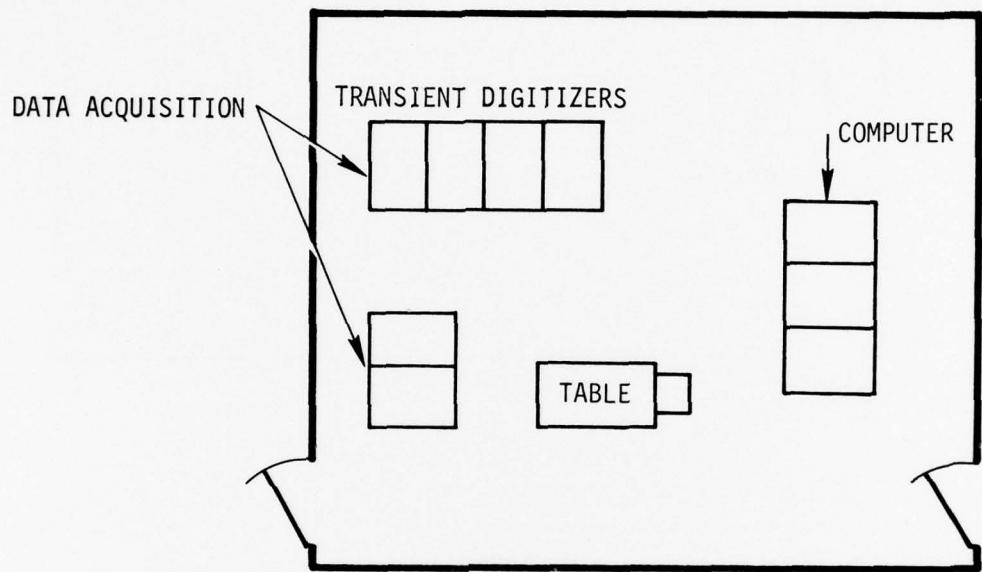
- CONTROL DATA
- VACUUM SYSTEMS
- PHOTON MACHINE SENSORS
- DOSIMETRY
- CONTROL COMPUTER
- AUDIO/VIDEO

SCALE
1.5 inches = 10 feet

RT-14555

Figure 3. Control data room

TRANSIENT DIGITIZERS

ACCESSORIES

COMPUTER

EXPERIMENT DATA

- EXPERIMENTAL SENSORS
- TRANSIENT DATA REDUCTION COMPUTER
- AUDIO/VIDEO

SCALE
1.5 inches = 10 feet

20 RACKS

USER DATA

- TEST SETS, MONITORS
- TELEMETRY EQUIPMENT

SCALE
1.5 inches = 10 feet

RT-14557
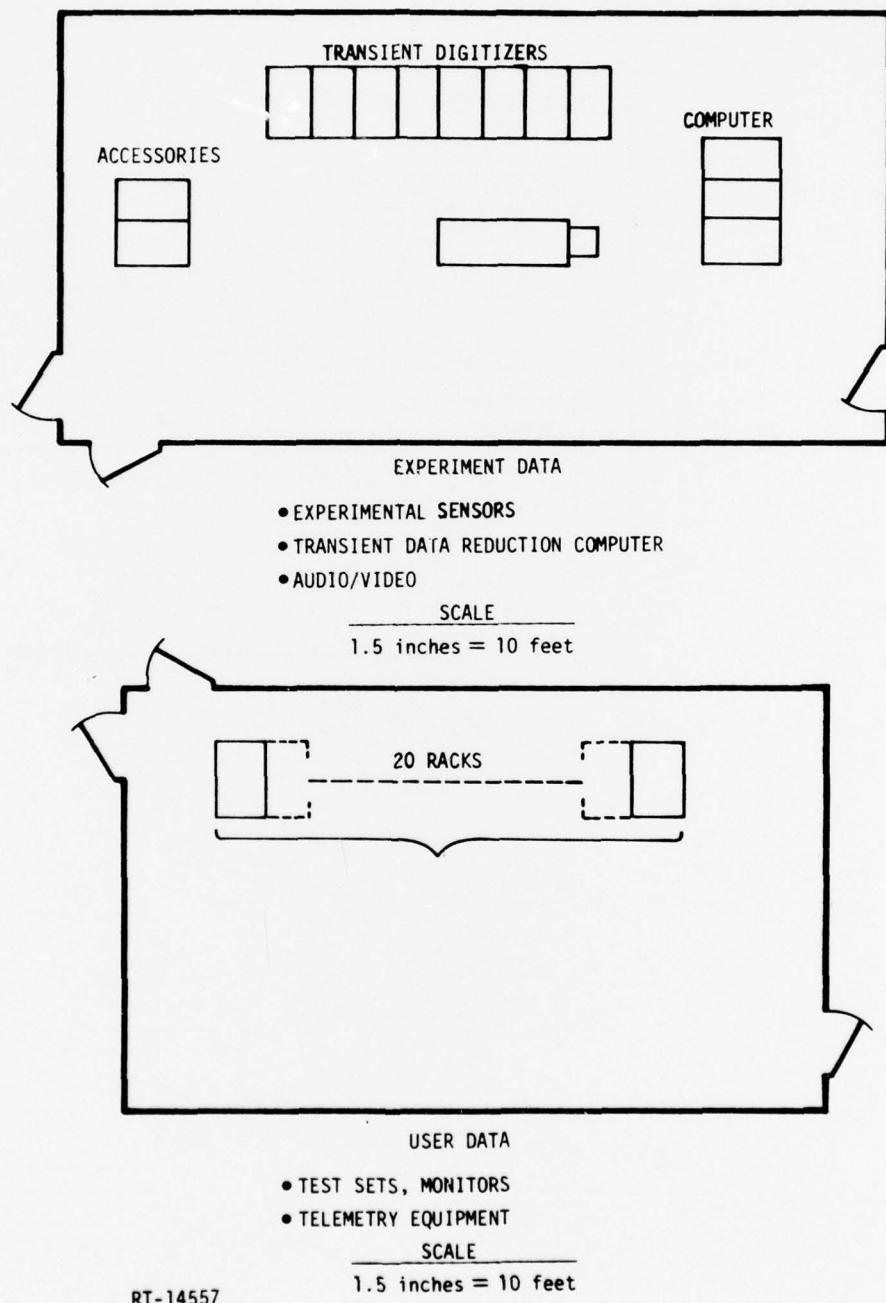
Figure 4. Data and user rooms

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GRID 1-M squares
1/4"x6" copper
strap, cover by
1-inch square
copper screen

— ATTACHMENT POINTS
x GROUND RODS

GROUND PLANE

VACUUM
CHAMBER

PHOTON
SOURCES

CONTROL

CONTROL
DATA

EXPERIMENT
DATA

USER

UNDETERMINED
MEASUREMENT

120'

RT- 14578
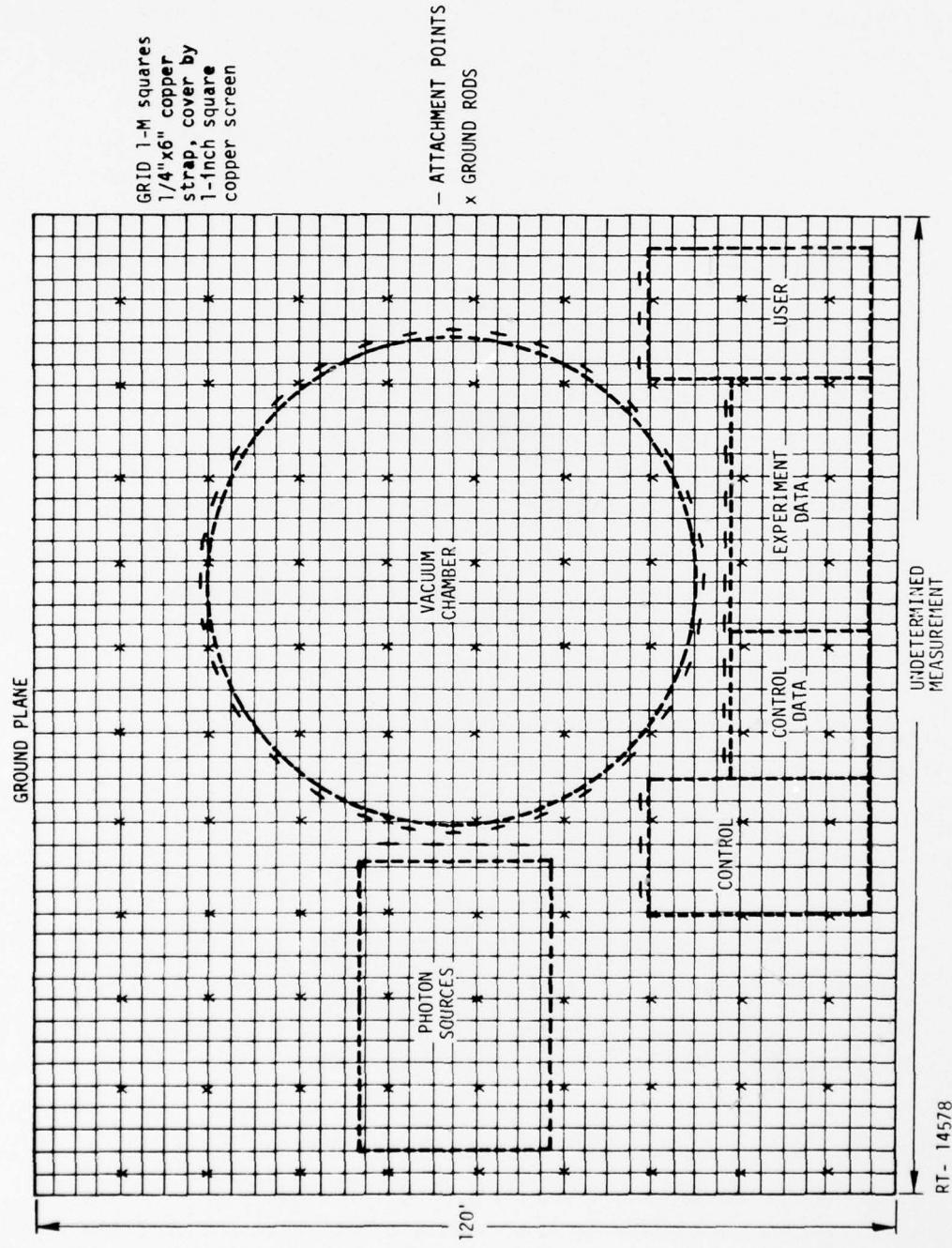
Figure 5.   Sub-floor ground plane

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The copper strap, screens, rods, and tie points are welded or soldered at all intersections. The copper straps provide low-inductance connections, while the copper screen is an economical method of creating a (cement) porous ground plane which will not support standing waves at the frequencies of interest. Details are shown in Figures 6 and 7.

The earthing rods provide a low-impedance ground to the earth which reduces the radiation of the test facility to other nearby facilities via RF and power line coupling.

Three system components are bolted to the ground plane. The photon sources, which might be removable, are connected along the vacuum chamber edge. The vacuum chamber is connected along its circumference. Each of these objects requires no special isolation from the concrete.

The RFI enclosure should be installed on an insulative pad. This initially allows the rooms to float. Once cabling is connected to the RFI rooms at controlled-penetration panels, measurements should be made to determine the noise between the ground plane and RFI rooms. The rooms may then be selectively grounded at one or several points along the vacuum chamber.

2.3 SIGNAL FILTERING

High-speed data on coaxial lines is not ordinarily filtered except by mathematical data analysis. Every attempt must be made to have all coaxial cables penetrate the RFI enclosure at a common point close to the enclosure ground tie point to prevent signal contamination by common-mode shield currents.

Slow-speed data may be readily filtered by networks, feedthroughs, and clamping techniques at the RFI enclosure wall. Differential data, e.g., that from thermocouple probes, should be filtered and buffered by amplifiers located at the enclosure wall to ensure common-mode rejection. Single-ended signals can then be carried to data reduction systems.

Coaxial and conventional signals which are common to the sections of the RFI enclosure should pass from section to section through bulkhead feedthroughs and filter elements to isolate each section from its neighbor. This is accomplished in the same fashion as external signal entry, with centrally

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SCREEN GRID ATTACHMENT
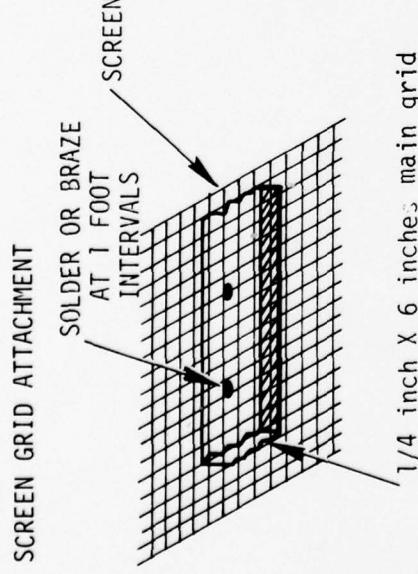
ENCLOSURE - GROUND ATTACHMENT

CONCRETE LEVEL

1/4 inch X 6 inches main grid

SOLDER OR BRAZE
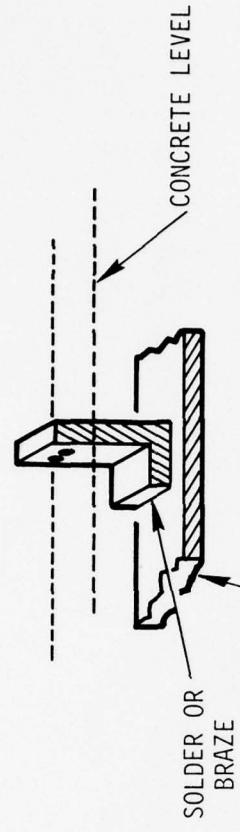
ALTERNATIVE CONNECTION

BRAZE OR SOLDER

NOTE: Use earthing rods for ground-plane leveling during concrete pour.

SOLDER OR BRAZE AT 1 FOOT INTERVALS

SCREEN

1/4 inch X 6 inches main grid

EARTHING RODS

BRAZE OR SOLDER

1/2 inch X 6 feet copper-plated steel

1/4 inch X 6 inches main grid
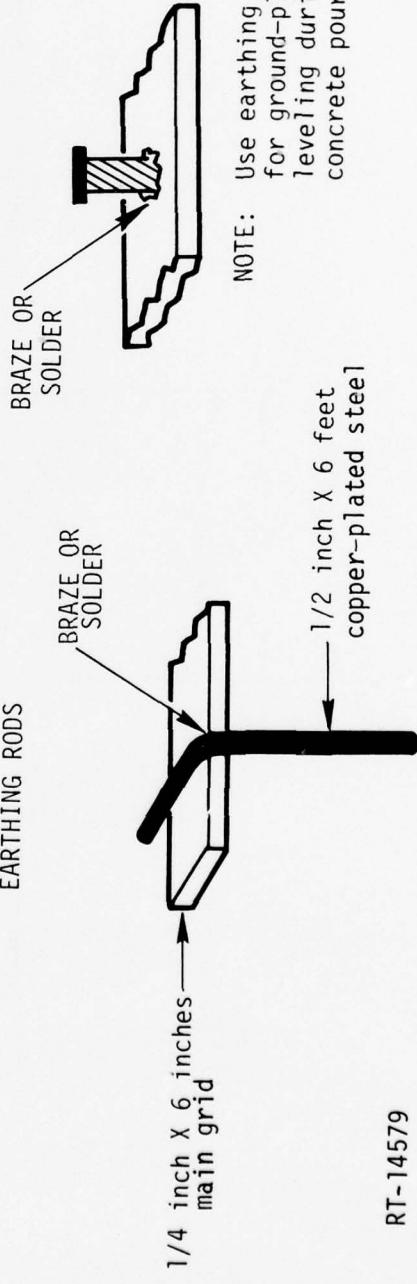
Figure 6. Ground plane details

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GROUND SCHEME - SIDE VIEW

|← 75' →|

VACUUM
TANK

MARX TANK
AND SOURCE

RFI
ENCLOSURE

INSULATIVE PAD

ATTACHMENT POINTS

GROUND-SYSTEM
PLANE

RT-14558
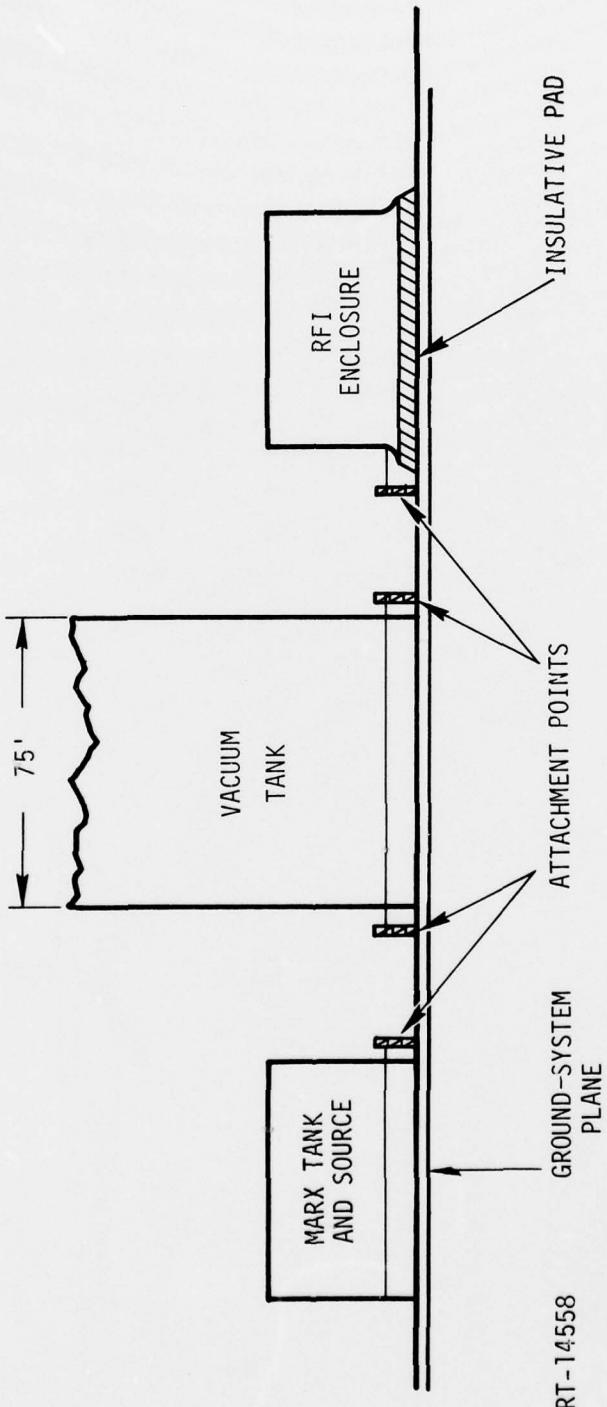
Figure 7. Ground plane--side view

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located penetrations and filter network arrays located under the computer floor between sections.

Optical and mechanical isolators are commonly used to control high-voltage supplies in overall control systems and to prevent feedback of switching noise to the control room.

2.4 GENERAL SPECIFICATIONS

ALL RFI ENCLOSURES

60-cycle power line filters per MIL-STD-220 and MIL-F-15733	100-dB attenuation from 15 kHz to 10 GHz
	5% maximum harmonic distortion at 50 Hz
	100 amp continuous operation

RFI Shielding

Electric fields and plane waves	120 dB above 1 kHz

Lighting

Dimable incandescent fixtures

CONTROL ROOM

Power requirements (three phase not required)	120/240 at 20 kVA
Air-conditioning heat load	20 kVA + 4 personnel 70 F - (24-hour operation)

CONTROL DATA ROOM

Power requirements	120/240 at 20 kVA
Air-conditioning heat load	20 kVA + 2 personnel (24 hours)

USER DATA ROOM

Power requirements (208V, three-phase may be required)	120/240 at 20 kVA
Air-conditioning heat load	20 kVA + 6 personnel (24 hours)

GROUND PLANE

Overall dimension - 120 feet x 150 feet

Main grid - 1/4 inch x 6 inch copper strap, brazed at laps

Depth in concrete - 3 inches

Earth ground rods - 1/2 inch x 6 foot copper plated steel

    Location: Driven into earth at 12-foot intervals

    Attachment: Brazed to copper strap

Screengrid - 1 to 2 inch copper screen

    Attachment: Brazed or soldered at intervals (every foot)
                    to copper strap grid

Above-floor attachments: 1/4 inch x 6 inch copper strap angles
                            brazed to main grid straps.

3. INSTRUMENTATION HARDWARE AND SOFTWARE

3.1 EXPERIMENTAL DATA ACQUISITION

3.1.1 Introduction

Overall control and data acquisition functions are shown in Figure 8. Control systems are found in Section 3.2.

Experimental data acquisition is concerned with the response of a satellite in SGEMP environment. It does not include the analysis of photon machines, vacuum systems, or other facility-provided systems.

User data acquisition is that data acquisition which requires user provided hardware or test sets.

3.1.2 Transient Data

The DNA SXT facility requires a system of fast transient digitizers connected to a computerized data reduction system. A system similar to that at the DNA CASINO facility can be utilized with modification.

The basic ingredients of this system are up to thirty-two R7912 Transient Digitizers coupled to a PDP 11/40 computer system.

Data from sensors on the test module or satellite will be connected to the digitizers by fiber-optic links such as the DNA-sponsored 400-MHz link.

An autocalibration and triggering system will ensure the correct performance of the digitizers prior to a test.

Background analysis is made in a normal operating sequence, followed by data acquisition and reduction. Calibrated, corrected waveforms of all sensors are then available to the experimenter. Several analysis techniques are possible. These include fast-Fourier transforms and inverse transforms. Signal splitting for analysis of data over different time intervals or sweep rates may be required. This can be recombined to give longer time-history information and resolution.
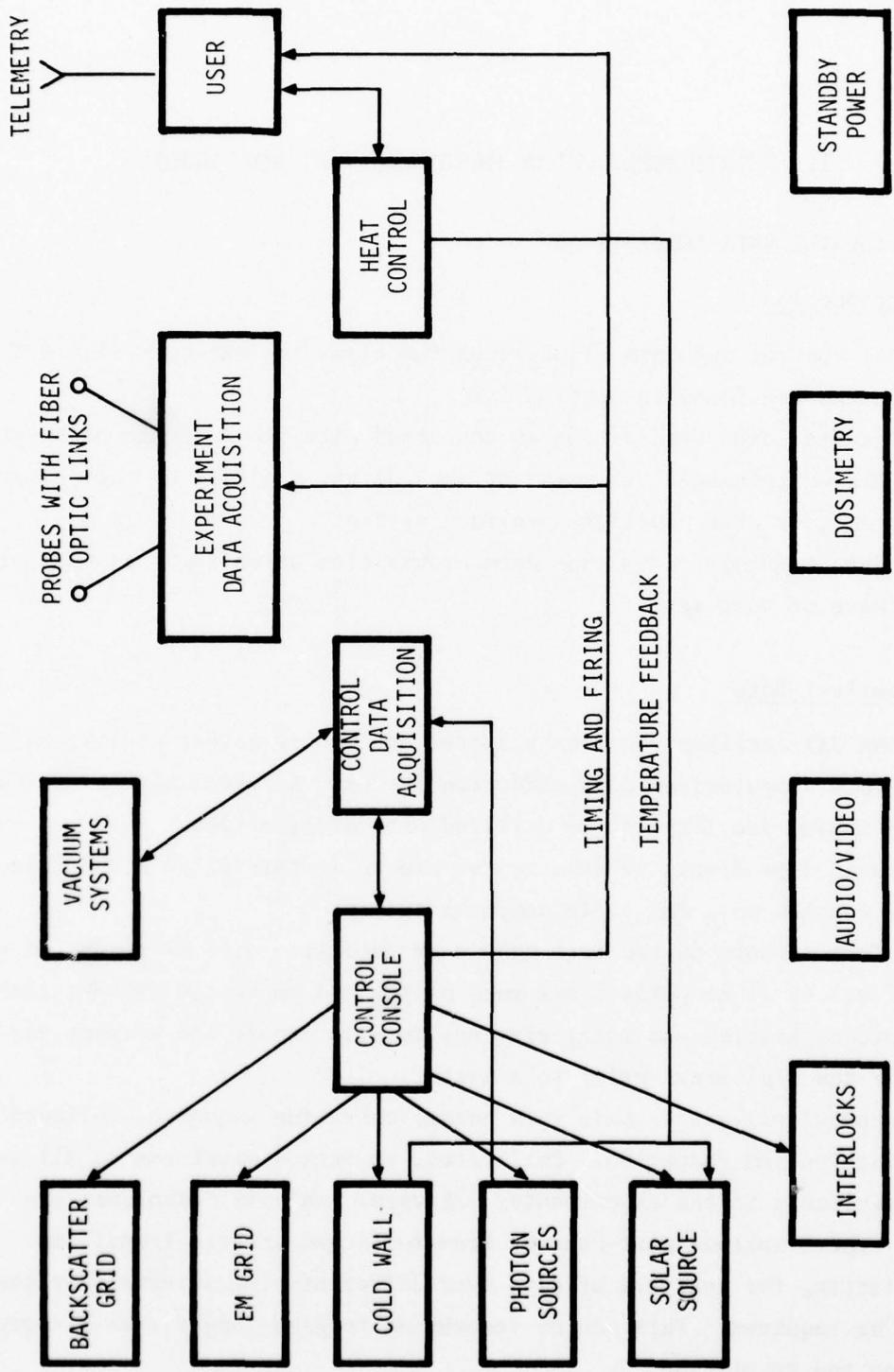
Figure 8. Control and data flow chart

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Several control features are required. These include remote power-up and attenuation of the fiber-optic transmitters, and a control console feedback system to indicate the status of the data processing system.

Figure 9 is a flow diagram of the major components of such a data acquisition system. Refer to Figure 4 for the room layout.

3.1.3 User Data Acquisition

User data acquisition is that system of instrumentation which is brought to the SXT facility with the particular test module or satellite. A room near the vacuum chamber and prep room is provided for this instrumentation (the User Room in Figure 4). It contains filtered power, communications, and chamber access cabling or feedthroughs.

Certain facility functions are provided for the user in this room. In addition to audio/video communications, these include timing and firing signals, temperature monitors, and solar source and cold-wall controls. Development of further user room instrumentation will require continuing interaction with prospective users and/or satellite manufacturers.

3.1.4 Specifications

EXPERIMENT DATA ROOM

Equipment (Major Items)

R7912 Tektronix Transient Digitizers	32 each
PDP 11 Computer (11T34) w/32K memory	
Floating head disk drives	2 each
Line printer/plotter	
CRT terminal	
Hard-copy unit	
Magnetic tape or cassette for data storage	
Fiber-optic data links	32 each
Audio/video communications and timing and firing	14 each
Estimated equipment racks	

USER ROOM

Equipment (Major Items)

User equipment	N/S
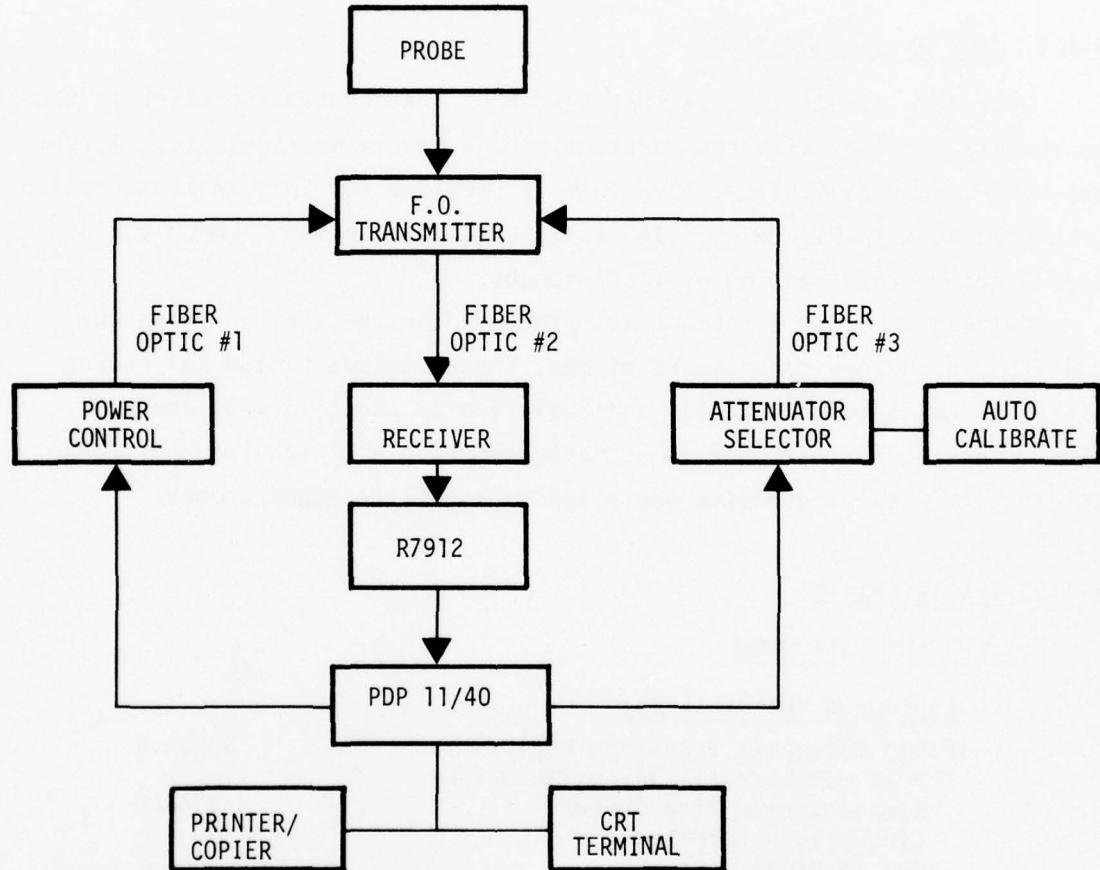
NOTE: #1 and #3 fibers may be combined.

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Figure 9. Data flow

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<u>USER ROOM</u> (Continued)

     Timing and firing console
     Audio/video communications

     Estimated equipment racks   Up to 20 each

<u>MISCELLANEOUS HARDWARE</u>

     Tektronix scopes w/plug-ins
     such as: 7904   2 each
                 7844   1 each
                 Storage Scopes   2 each
                 454 Portable Scope   2 each
     Scope cameras   N/S
     General-purpose pulse generators
     Time-domain reflectometer
     Delay generators

3.2 FACILITY CONTROL INSTRUMENTATION

3.2.1 System Integration

Facility control instrumentation is the system of controls and data acquisition necessary to operate and monitor all major and minor systems and components of the DNA SXT facility in a consistent, coordinated manner. Thus, facility control is both an instrumentation task and a systems integration task.

Figure 8, shown previously, is a block diagram of the systems requiring facility control. The photon machines, which may be of different manufacture, will be integrated by a central control scheme that will provide the appropriate timing signals to each machine for synchronous firing. This can be most conveniently accomplished by coordinating the central control with the control consoles of the two machines during the design and production stages of the machines.

In Section 3.2.2, data acquisition for the photon machines is discussed; this also includes the recording of performance parameters for the two machines, such as charge voltages, gap settings, and time delays.

The facility control console will require a complex logic system that will prevent machine firing if all safety interlocks and system monitors are not satisfied, i.e., within operational limits. Such diverse operations as data acquisition readiness, vacuum measurements, and satellite status will have input to the facility control console.

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3.2.2 Control Data Acquisition

Because of the slow repetition rate of the anticipated tests, actual
countdown and firing sequences will be controlled manually by an operator in
the facility control room.

However, a computer will be used to log parameters and acquire data from
almost all control functions. This control data aystem will have two major
functions, which are the control and operation of the chamber vacuum system and
the acquisition of photon-machine diagnostics data. Minor tasks will be to
monitor and log knob settings, switch positions, temperature and transducer
outputs, and all parameters critical to the proper operation and performance
of the test event.

While the ultimate design of the control-data computer system results
from the design of the photon machines, vacuum systems, and other systems
such as cold wall and solar source, the system is expected to have the
following features:

1. A PDP 11/40 is selected and configured with main elements of
    the data acquisition computer, which is also a PDP 11/40.
    This avoids software redevelopment and reduces staffing associ-
    ated with the computer operation. The PDP 11/40 is selected
    because it is directly commercially interfaced to the R7912
    transient digitizers, which are required both in the control
    data system and the (SGEMP) data acquisition system. Also, there
    is a significant amount of software which has been generated under
    Government contract for this combination.

2. A standardized CAMAC crate system is selected and used for data
    logging and vacuum system control. A wide variety of standard
    CAMAC hardware, as well as the PDP 11/40 interface, is available
    from numerous manufacturers. This ensures reliable system per-
    formance and easy maintenance.

Only where commercial hardware is unavailable or unacceptable will custom
construction be necessary. This policy will reduce the cost of "one-time"
design, construction, and documentation, and will simplify maintenance and
operating costs.

3.2.3 Subsystems

3.2.3.1 Photon Source Control. The photon sources, possibly of different manufacture, will generally include control consoles for operation and control. These consoles may require modification to integrate them with the overall facility control system. This task should be performed at the time of console design and specification.

Since the photon sources require critical timing and are the main event of the SGEMP test, it is difficult, if not impossible, to design a central control without sufficient knowledge of the machines. However, prior to source selection, a survey of source manufacturers would characterize the types of timing, signals, and feedback necessary to operate the machines so that preliminary specifications could be developed. The central control console is a systems integration problem, since it must direct and provide the appropriate signals to two different machines and to all other systems that require information or triggers during the test. It will be the last item to have a completed design, although the design effort will have to begin with the earliest subsystem design.

As mentioned in Section 3.2.2, a general design policy will be to log data digitally from the photon machine control consoles and the central console in a normally passive operation, i.e., set points and sequences will be manufally determined with the data logger or control data computer simply tabulating the results. Fast sequential events will be programmed from a system timer with the control data computer providing warnings and fault indications as necessary. The design goal is not sophistication, but ease of operation and simplicity of design.

3.2.3.2 Cold Wall. The DNA SXT facility will probably require a cryogenic cold wall system, the purpose of which is to provide thermal control for satellites under test. Some of the requirements suggested by satellite manufacturers are presented in Appendix A. It appears that the cold wall should consist of several sections with independently controlled temperatures over the range 77 to 300°K. Fast dump capability is considered essential. The cold wall must be compatible with the EM damper system.

Control of the cold wall is exercised primarily through control of electromechanical valves in the liquid nitrogen (LN_2) and gaseous nitrogen (GN_2) systems servicing the cold wall. Fast, accurate temperature sensing is required, properly designed resistance or thermocouple sensors probably being suitable. Remote control of positioning (e.g., retractable walls) may be necessary. Operation of the entire cold-wall control system should be possible from the facility control, control data, and user data rooms, since satellite thermal balance must usually be controlled by the experimenter.

The following information is needed in the development of a suitable cold-wall design:

- Determination of the most suitable wall configuration compatible with the EM damper.

- Determination of the LN_2 and GN_2 flow control requirements, including assessment of special features necessary for fast dump capability.

- Calculation of the speed attainable for fast dump and the resulting vacuum-system gas load.

- Coordination of the cold-wall instrumentation with the overall facility instrumentation.

3.2.3.3 Solar Source. The need for a solar simulator in the DNA SXT facility has yet to be established. Assuming that solar illumination capability will be necessary, the mechanical configuration and placement of the simulator must be compatible with the EM damper (which has not yet been designed). The heat load on the cold wall must also be taken into consideration. In consideration of possible tests on spinning satellites, an array of as many as six sources may be required (c.f. Appendix A). Planning of the simulator instrumentation must take into account the possibility that spectral monitoring and control may be necessary in addition to that for intensity.

Assuming, then, that a full solar simulator system with spectral tailoring capability is required, the unit would probably consist of arc lamps with associated power and control systems. Spectral tailoring is accomplished

through adjustment of gas mixture, e.g., Ar and Xe. The subsystems are:

1. power supply, cooling, and control circuitry

2. gas supply and mixing control

3. intensity sensor system

4. spectral sensor system.

Some anticipated characteristics of these subsystems are indicated in the following:

1. The power supply is conventional, but the power-control circuitry is required to interface to facility control. Data from the intensity sensor system is processed and used for adjustment of the power level to the lamp. Thermal sensors are required in the cooling system.

2. Instrumentation is required in the gas supply system for pressure monitoring and control, and for gas species mixing control. Pressure sensing is accomplished, for example, by strain gauge transducers. Valves are operated by electronic commands, allowing control of pressure and gas mixing.

3. Sensing of the illuminance produced by the lamp is anticipated to be necessary for assuring proper solar levels during experiments. As many as ten sensors may be required. Protection of the sensors from x-ray damage and access to the sensors after pumpdown are considered to be desirable features. As an alternative to placing solar sensors in the vacuum chamber, a fiber optics scheme is suggested. In such a system, an individual sensor assembly would consist of a small input lens and fiber optic cable within a vacuum chamber, coupled through the chamber wall to a silicon photodiode--optical amplifier unit. Proper spectral response of the sensor can be established with an appropriate filter on the photodiode. Advantages of this technique for conducting the light to outside sensors include

radiation hardness, stability, accessibility, ease of inter-
face with facility control, and low cost. Analog voltage out-
puts of the sensor amplifiers are multiplexed, digitized, and
read by the facility control computer.

4. If spectral tailoring is to be performed, means should be pro-
    vided for determination of the spectral distribution of the
    illumination. The coupling of light to external photodiodes
    by means of fiber optics appears to also be advantageous for this
    application. A sensor can then be composed of an input lens, a
    fiber-optic cable, a set of silicon photodiodes with bandpass
    filters, and an operational amplifier for each photodiode.
    Amplifier outputs are multiplexed and digitized for input into
    facility control. It should be noted that spectral sensors yield
    intensity information, as well as information on the lamp spec-
    trum. An alternative scheme is to couple the fiber-optic cable
    output into a scanning spectroradiometer.

3.2.3.4 <u>Backscatter Grid</u>. Simulation quality in the DNA SXT facility
will probably require control of electron backscatter, either through passive
(wall coating, source collimation) or active (grid) means. If the active
option is taken, the only instrumentation required is a 50- to 70-kV power
supply with proper safety interlocks and with digital interface to facility
control. The supply voltage is programmed by computer command and information
on the operational status of the unit should be sent back to the computer.
Suitable power supplies with digital programming are presently available.
Specification of the current capacity of the supply will require an estimate
of the backscattered electron current, which is a function of the source
fluence and collimation, the minimum satellite size, and the wall material
(or coating). An estimate should also be made of induced currents produced
in the grid-power supply system by the photon-source field pulse in order
to assess the RFI protection requirements for the supply. Once these parameters
(or their limits) are specified, characterization of the power supply system
follows directly.

3.2.3.5 Emergency Power. The satellite x-ray test facility will require
an emergency power system to protect vital systems and operations in a power
outage. Each subsystem must be examined to determine the requirements for a
fail-safe mode of operation. Of particular concern is the vacuum system,
cold wall, solar source, and user instrumentation. An emergency power system
should provide for an orderly shutdown of these systems to prevent damage to
the test module and facility instrumentation.

The use of emergency power to continue a complete test is desirable but
extremely costly. The vacuum system alone may require 2 megawatts of power.
An orderly shutdown scheme will require much less hardware. In addition,
delays caused by power outages are infrequent and of short duration.

The conceptual design for emergency power is to use motor generators
that would operate during critical phases of the test event.

Exact emergency power requirements have not been determined. It is
important to minimize these requirements, since motor generators, typically
diesel powered, are high-maintenance items which could impact facility
staffing estimates.

3.2.3.6 Vacuum System. The vacuum system instrumentation will consist
mostly of vacuum sensors valve controllers, and pump-power controllers.
Typical vacuum sensors include:

- strain gauge transducers   >1 torr   (>10 required)
- thermocouple or Pirani gauges 10^{-3} to 1 torr   (>10 required)
- ion gauges (conventional) $<10^{-3}$ torr   (>10 required)
- ion gauges (Schulz-Phelps) 10^{-5} to 1 torr
- residual gas analyzers $<10^{-3}$ torr   (>2 required)

In addition, one or more capacitance manometers may be necessary for calibra-
tion checks of other gauges, and a leak-testing facility is desirable. The
number of sensors and controllers required will depend upon the physical
design of the vacuum system. All sensor, valve, and power controllers are

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to include digital interfaces to the system control. Such controllers with
digital I/O are standard items available from several manufacturers. It is
anticipated that operation and monitoring of the vacuum system will be auto-
matic. It may be advantageous to dedicate a single processor to vacuum control
and monitor tasks. That processor would then communicate with the facility
control computer on an as-needed basis.

3.2.3.7 <u>Magnetic Environment</u>. The effect of the geomagnetic field on
simulation quality in the DNA SXT facility is presently under study. Should
geomagnetic field suppression be necessary, the vacuum tank would be provided
with a set of external field coils. Data needed for the detailed field coil
design and current optimization are provided by a magnetic field map of the
interior of the vacuum chamber.

If the geomagnetic field were the only field present in the chamber, the
instrumentation requirements would be straightforward. The internal field map
can be produced with, for example, a dual rotating coil magnetometer mounted
on an appropriate carriage and boom. Suitable magnetometers are available
commercially. Occasional verification of the field map may be necessary, so
that the magnetometer unit should be readily transportable and easily indexed
into position in the tank. With only the geomagnetic field present, a per-
manently mounted magnetic field sensor within the vacuum chamber would probably
not be necessary.

Power supplies for the field coils are expected to be of conventional
design. Coil currents are set by digital signals from the facility control
computer to the power supply controllers. The number of supplies and control-
lers and the current requirements can be specified only after the vacuum wall
material is chosen and a preliminary design for a field coil arrangement is
completed.

After suppression, the magnitude of residual geomagnetic field in the
chamber would be a few milligauss. However, the possible presence of other
fields must be considered. High-current wiring and rotating machinery, for
example, may produce a 60-Hz a.c. field in the tank. Some magnetic shielding
against a.c. fields may be provided by the metal chamber walls if the wall

thickness is greater than the skin depth at 60 Hz ($\sim$1 cm for aluminum). Nevertheless, some care should be exercised in the overall electrical design of the facility in order to minimize a.c. magnetic fields.

3.2.3.8 <u>Safety and Communications</u>. The DNA SXT facility will require a system of interlocks and monitors to control the access of personnel to dangerous areas when equipment is operating, i.e., when the chamber is being evacuated, the Marx tanks are changing, etc. This system excludes security, which is the responsibility of the operating agency.

As system designs are finalized, it will be the responsibility of the system integrator to establish and direct the incorporation of safety inter-locks and video monitors into the facility and component construction.

Communication systems have useful safety applications, as well as prac-tical considerations. Video monitors and cameras are to be placed at appro-priate locations in the vacuum chamber and around the Marx tanks for remote observation, remote handling, and personnel interactions. Intercoms and headsets will be used in the preparation of systems which have connections or interfaces in more than one area. Telephones and loudspeakers will be provided for communications between experiments and technicians. The entire facility will have a uniform intercom and paging service for fast, efficient operation.

3.2.3.9 <u>Remote Handling</u>. Remote handling refers to the problem of satellite positioning by remote control if the vacuum chamber is evacuated. This is to be accomplished in conjunction with a video monitor. Controls will be either electromechanical or pneumatic, separated from the user data room.

3.2.4 <u>Specifications</u>

<u>CONTROL ROOM</u>

<u>Equipment (Major Items)</u>

Photon-source operation consoles   Not specified

```
Operations interface console w/timing
and firing systems, safety interlock
systems, and audio/video communica-
tions                                          10 each

Estimated equipment racks                      10 each
(includes source consoles)
```

CONTROL DATA ROOM

Equipment (Major Items)

```
R7912 Tektronix Transient Digitizers      16 each

PDP-11 Computer (11T34) w/32K memory,      1 each
   floating-head dish drives,              2 each
   line printer/plotter, CRT terminal,
   hard-copy unit, and magnetic-tape
   or cassette unit

CAMAC Crate Systems N/S                     2 each
for control room data management
and vacuum system management

Audio/video communications and timing
and firing

Estimated equipment racks                  10 each
```

3.3 SOFTWARE

A major segment of the instrumentation system will be the programming
of the control data computer and the data acquisition computer. Although
similar software has been developed for the DNA CASINO facility, modification
to this and other software must be made to incorporate such software into the
new SXT facility.

It is a design policy to use the same software format and system for
both computer systems. This reduces the staffing and maintenance requirements
of the facility. In addition, software development will proceed prior to and
through system acceptance and testing. The procedure is a three-stage develop-
ment philosophy that includes: (1) building a working data system on best
available design information; (2) modifying it during acceptance and facility
tests to fit and emphasize practical needs; and (3) expanding the software base
for unforeseen SGEMP analysis requirements as an ongoing software service.

3.4 DOSIMETRY

A separate but important function essential to the proper operation of
the DNA SXT facility is the dosimetry of the photon-source output. Dosimetry
should be a service provided to all experimenters who require regular informa-
tion on spectrum and dose. In addition, a well-organized dosimetry lab will be
required during checkout and acceptance tests.

Dosimetry within the vacuum chamber will require special techniques because
of the long pumpdown and repressurization time. Active dosimetry such as
thermocouples and biased diodes can be immediately acquired, but spectrum
unfolding methods such as graded Z stacks and dose distribution diagnostics
using TLD's may require vacuum penetrations for access and removal.

Table 1 is a survey of dosimetry available for the DNA SXT facility.
All active dosimetry will be acquired by the control data computer.

TABLE 1.   DOSIMETRY TABLE

	Type	Yield
Sensor		
Calorimeters	(active-thermocouple)	Total energy
TLD's	(passive)	Dose distribution
Photodiode	(active)	Dose rate
Compton vacuum diodes	(active)	Dose rate energy dependent
Bias diode	(active)	Electron spectral unfolding 1 to 10 kV
Dye film	(passive)	Total dose distribution
Pin hole	(passive)	Source geometry
Spectrometers		
Multifoil	(passive-TLD)	Dose depth profile
Graded Z-stack	(passive-TLD)	Energy in bins
Bent crystal	(passive film)	Spectrum
Cylindrical mirror	(active-collectors)	Spectrum
Magnetic	(active-collectors)	Spectrum
Satellite Sensors		
B, $\dot{B}$	(active)	
E-field	(active)	
Skin current	(active)	

4. COST ESTIMATES

Since control room functions will include the monitoring and operation of two photon sources (possibly of different manufacture), the vacuum system, solar light source, cold wall, timing and firing, and safety interlocks, a major task will be the coordinated systems integration and interface of this variety of equipment into a consistent, operational unit. This task will require a continuous-level high activity from the initial design of the facility through the first experiment.

Data-reduction software for both the control-room data acquisition and the experiment data acquisition will require a one-year lead time and should be initiated during the instrumentation design phase. Software services will be required throughout the useful life of the facility, although decreased activity is anticipated after the facility acceptance.

Fiber-optic data links are the most desirable method of measuring SGEMP signals without system distortion. Commercial wide bandwidth links are not readily available above 200 mHz. However, developmental models have been demonstrated at 400 mHz, which would be adequate with some miniaturization. Thus, estimates on purchasable fiber-optic data links are quite speculative.

COST SUMMARY (FY 78)

EQUIPMENT

|	
RFI enclosures (beyond normal construction)	100K
2 each - Computer systems with disk drives and peripherals	160K
48 each - Transient digitizers @ 20K each	960K
Miscellaneous special-purpose data acquisition hardware	60K
Oscilloscopes and measurement equipment	100K
Fiber-optic data links	200K
Support hardware, including cabling, isolation transformers, audio and video equipment, and safety systems	*100K*

MANPOWER

Control systems and facility instrumentation integration	500K
Software systems	500K
TOTAL	$ 2,680K

Note: These figures do not include the photon-source control console which would be manufacturer-provided, nor do they include gauges, pumps, and controls such as power contactors that are integral parts of the various subsystems.

5. SCHEDULING

The development of instrumentation for the DNA SXT facility involves many interrelated tasks. For some tasks, the characteristics of the photon sources must be known. For others, the configurations of the EM damper, solar source, cold walls, etc., must be specified. Thus, only tentative scheduling of the instrumentation development program is possible at this time. Such a tentative schedule and its relation to the present program plan is given in Table 2.

Table 2. Program Plan Schedule

CONCEPT DEVELOPMENT
DESIGN DEFINITION
SOURCE SELECTION
VACUUM DESIGN
INSTRUMENTATION DESIGN
BUILDING SPECIFICATIONS
SOFTWARE DEVELOPMENT
SOFTWARE SUPPORT
CONSTRUCTION
ACCEPTANCE
PHOTON SOURCE DELIVERY
INSTRUMENTATION DELIVERY

1976 J S M 1977 J S M 1978 J S M 1979 J S M 1980 J S
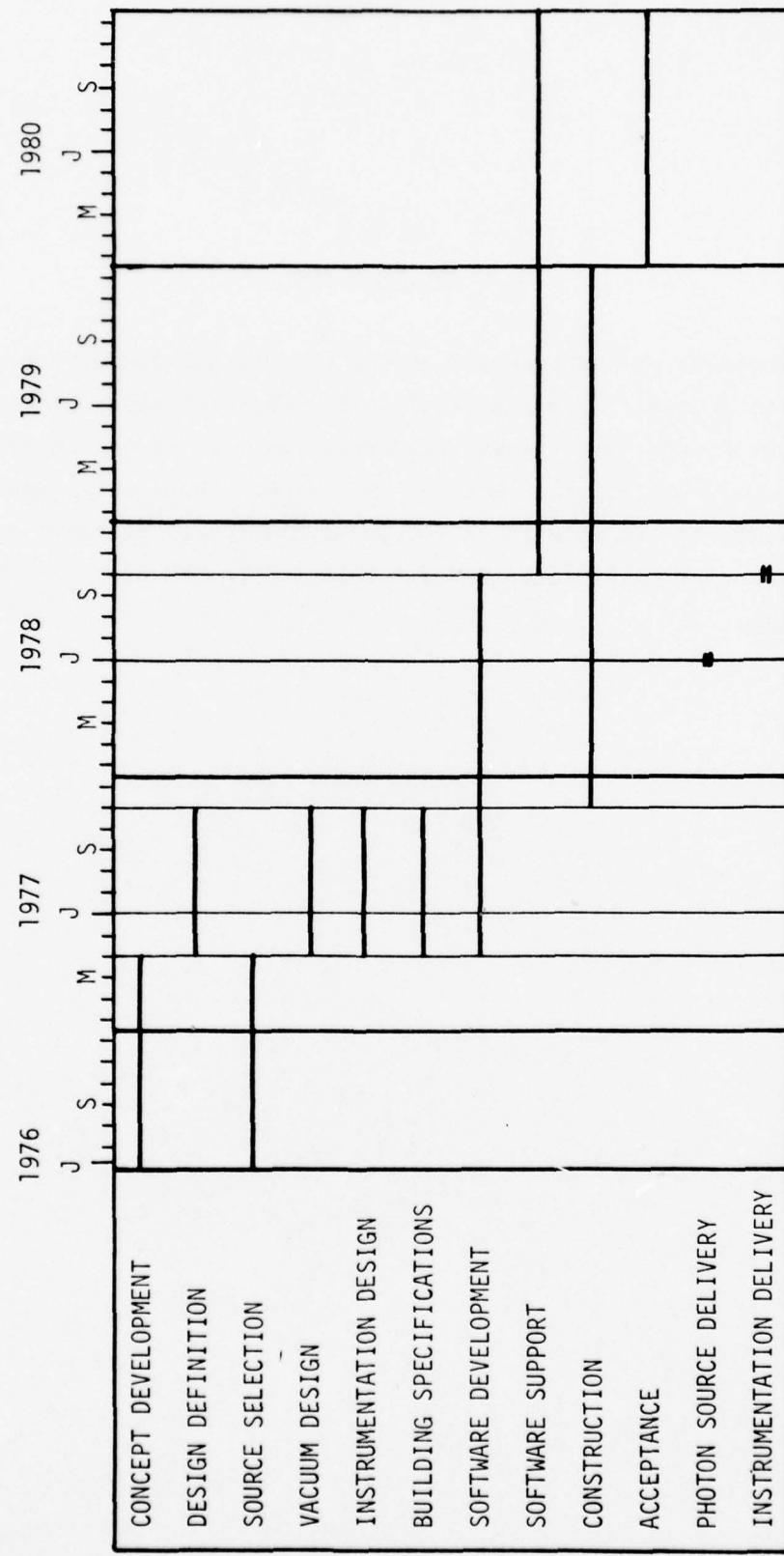
APPENDIX A

A series of visits was made by R. Keyser and R. Galloway from IRT and N. Carron and L. Cotter from MRC to the following satellite manufacturers:

Aeroneutronic Division of Ford
Hughes Aircraft Company
General Electric (Valley Forge)
RCA (Highstown, New Jersey)

This appendix summarizes the requirements of an SXTF as viewed by representatives of those manufacturers.

A.1 INTRODUCTION

This appendix documents the results of a series of discussions with satellite manufacturers on what is required in an SXT facility to operate their spacecraft. A discussion of SGEMP response measurement instrumentation is also included. The findings will be discussed in detail in the following sections with a brief overview of the results included here.

The test, which is envisioned for the satellite in the photon environment, represents a more comprehensive test than is ever performed on a satellite prior to launch. Testing of a satellite is normally accomplished as a series of individual tests, each emphasizing a particular subsystem, and the sum of these tests constitutes a complete test. This greatly simplifies the process, since conflicting requirements are eliminated (e.g., the need for an RF anechoic environment for complete transponder testing versus the need for a vacuum environment for thermal-vac tests). But the SGEMP test is to be on a completely operational satellite, with all systems up and working, in a vacuum environment, and with the satellite electrically isolated (which means that the RF links must be operating). Thus, it poses new problems such as how to test the transponder of a communications satellite in a vacuum tank without being able to hardwire to the satellite.

One of the most significant problems is how to power the spacecraft. The tentative conclusion is that a solar simulator, optimized to the solar array response region, is required. Cold walls with controllable temperature

are also required to maintain an acceptable thermal environment. (Thermal control was probably the most emphasized requirement by all the satellite manufacturers visited.) Some alternatives to radiating full RF power, especially for transponders, is required so that the spacecraft can be properly controlled and prevented from damaging itself. There is no need to cancel the earth's magnetic field in the tank from the standpoint of satellite operation. Transportation of the satellite to the test facility is not an important consideration.

A plan view of a facility which incorporates the requirement determined in this survey is shown in Figure A-1.

A.2 SIZE, WEIGHT, AND HANDLING

The weight of current spacecraft is 2,000 to 3,000 pounds. This is likely to increase to 4,000 to 10,000 pounds during the space shuttle era. Size is typically 10 foot dimensions on body size, with some to 15 foot lengths. Wing-spans on three-axis stabilized spacecraft, which is now the trend, are of the order of 30 to 50 feet.

The largest shipping container is of the order of 10 x 10 x 25 feet and weighs 2,000 pounds. The larger ones have wheels and can be rolled around. Smaller containers can be handled by forklift. All can be handled by over-head crane, and this is the preferred way. It should be noted that overhead cranes and other lifting devices will have to be periodically tested and certified. Shipping containers with spacecraft inside can be shipped via air-ride van or Government-furnished airlift if schedule requires. Transporta-tion does not pose a serious problem.

Handling of spacecraft is almost always accomplished at the separation plane between spacecraft and launch vehicle. Fixtures are always made to handle each type of spacecraft, and these will be available for the setup area and for rolling the spacecraft into the tank or area where it will be lifted. In addition, some means of lifting the spacecraft is always provided, e.g., suspension points or hard points on the main structure. Where suspen-sion points are available right on the structure, it will be simple to hang the satellite from dielectric lines to achieve an isolated suspension.
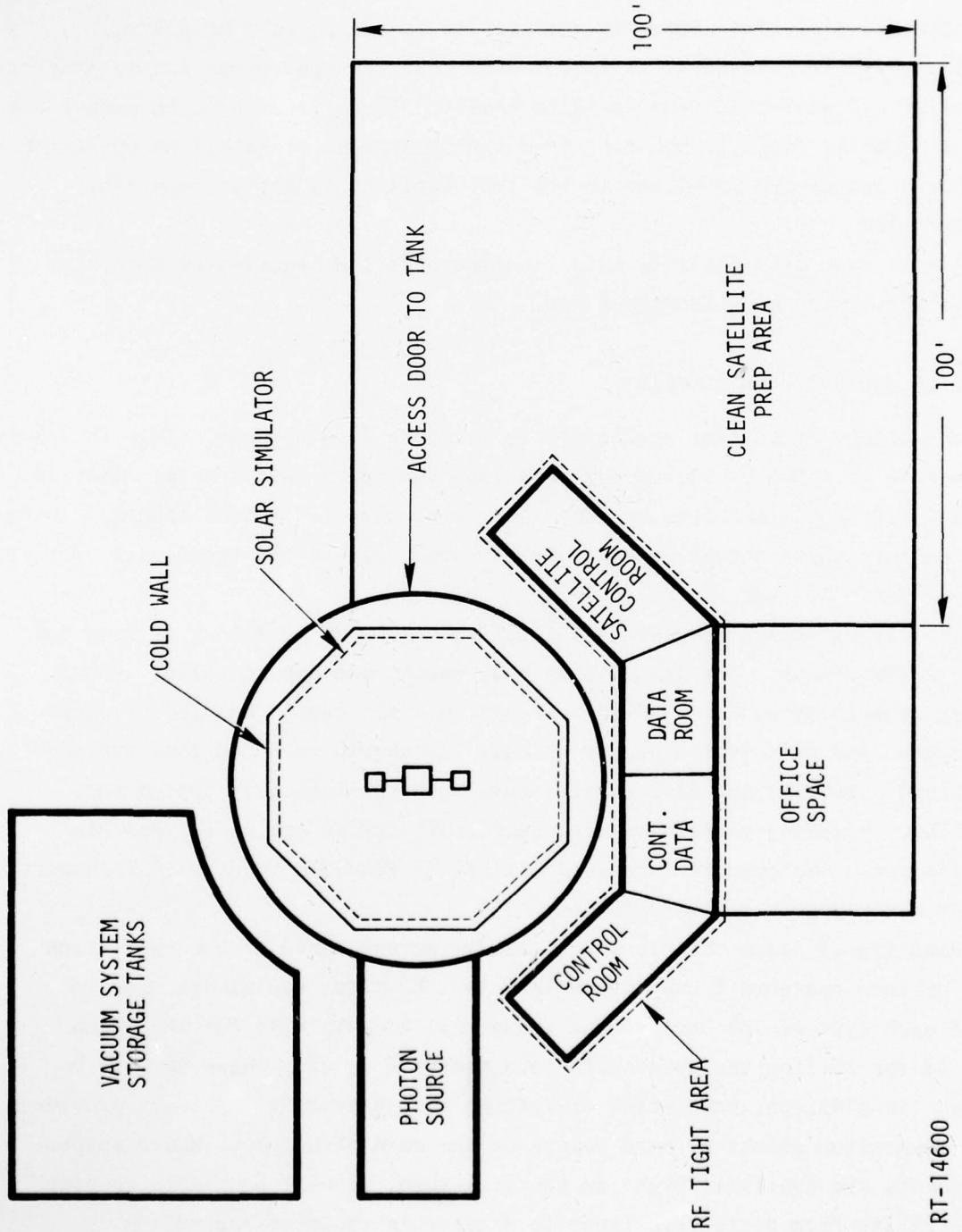
Figure A-1. Overview of satellite x-ray test facility

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However, it may not, and probably will not, be possible to place the space-craft in arbitrary orientations using these suspension points, since the structure may not be stressed properly except for the "usual" orientation. In addition, to attach to the hard point on some spacecraft requires a fixture which would disturb the electromagnetic properties of the simulation.

Spacecraft can be placed in any arbitrary orientation when handled at the separation plane, but building a dielectric platform capable of carrying the loads will be a problem. Hanging them upside down from the separation plane with lines from other structural points to pull them into skewed orientations is a possibility. Some additional stress analysis on each spacecraft will probably be required to determine just what is feasible for that particular spacecraft. If arbitrary incidence of x-ray photons is an absolute must, it may be necessary to build the source so that it can be placed in two or three different locations in the tank wall.

All deployable appendages, particularly solar paddles, will have to be placed on the spacecraft after it is hung. They will also have to be supported separately, except in rare cases.

A.3 ENVIRONMENTAL CONSIDERATIONS

Cleanliness of the areas where the spacecraft is located does not appear to be a serious problem. Satellite manufacturers assemble and operate their spacecraft in class 100,000 clean facilities generally. Frequently they do not actually monitor the quality of cleanliness, but just use the appropriate techniques, e.g., smocks, no eating or drinking in areas, double doors (some-times with positive pressure), etc. They say that these are as much psycho-logical as anything, since they tend to promote careful workmanship. For opening and working on "moving mechanical assemblies", class 100 cleanliness is required, and for optical instruments class 10,000. However, these opera-tions are not likely to be required at the SXT facility. They recognize that class 100,000 cleanliness is not maintained in even their own vacuum tanks, and accept whatever level of cleanliness is available so long as an attempt is made at reasonable cleanliness. While placing the spacecraft in the tank, it will probably be kept wrapped in plastic as an additional protective measure.

Temperature and humidity must be controlled at all times in all areas where the satellite is located. Temperature is room temperature plus or minus 5 to 10°F. Humidity is 45$^+$ ±15%, except for one manufacturer, who specified less than 50%.

Controlling humidity and contamination during pumpdown and repressurization is likely to be the most serious problem. For example, to control humidity and condensation during pumpdown, it may be necessary to purge the tank and possibly to use a cryotrap to deposit moisture after pumping begins.

Similarly, during repressurization it may be necessary to fill the tank with dry air or nitrogen before opening it to air. It is also necessary that the spacecraft be at room temperature before opening if it has been allowed to get colder than room temperature. Care must be taken to prevent contamination during repressurization.

A.4 POWERING AND OPERATING SPACECRAFT IN TANK

Providing power to the satellite and an acceptable thermal environment for operation are probably the two most important factors to be considered in the facility design. These and other operational considerations will be discussed here.

Battery power alone is inadequate to operate spacecraft for more than a few hours at most, especially at full power. Most spacecraft are capable of operating on batteries for a much shorter time, and some even require that the spacecraft be put in a minimum power mode when on batteries. All of the spacecraft manufacturers contacted strongly favored a means of powering the spacecraft so that continuous operation can be achieved, rather than relying on batteries, which will eventually die. In fact, this really appears to be mandatory, since TLM is required during pumpdown and venting (and all the time between) so that spacecraft temperatures can be monitored. Choices for powering the spacecraft during the test then appear to be:

- through an external cable only
- from batteries which are used during the test and then recharged (and the spacecraft powered) via a cable that can be disconnected and reconnected
- from the solar arrays.

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The first two results in a lower cost facility, but suffer from poorer simulation of the operational situation. The third choice produces a better operational simulation, but requires more of both the facility and spacecraft. The additional facility requirements are a solar simulator with the right spectrum to activate the solar cells (but not a perfect match of the sun's spectrum) and increased cold-wall capability. The additional spacecraft requirement is for a full complement of solar cells, which is not usual for qualification models of spacecraft. Thus, the full complement would have to be added or else flight solar panels would have to be substituted. Use of flight panels would, in turn, probably limit the amount of radiation exposure the spacecraft could receive. At the present time, inadequate data are available for choosing between these alternatives. Studies of the effect of a cable-to-spacecraft conductive or capacitive coupling on the SGEMP response should be made, as well as studies of the importance of illuminated versus nonilluminated solar arrays on simulation quality. For the present time, it will be assumed that a solar simulator will be used to power the spacecraft.

The solar simulator need not be matched to the sun's spectrum, but instead matched to the response region of solar cells, i.e., 0.4 to 1.1 microns. This means a lower cost simulator and lessened cold-wall requirements, since the spacecraft is not being heated fully by the sun. The simulator has different optimum configurations for spinning and three-axis stabilized spacecraft. For spinners, it will not be possible to spin the spacecraft because of the requirement for dielectric isolation. For proper thermal balance the solar simulator will therefore need to surround the spacecraft so that what heat input reaches the satellite from the simulator will be uniformly distributed. The intensity will also be less than full to prevent overloading the power-conditioning equipment. For three-axis stabilized spacecraft, the solar simulator should be variable with respect to the spacecraft and x-ray source so that arbitrary positioning of the spacecraft and solar arrays can be achieved. The optimum solar array simulator configuration, then, consists of six individually controllable arrays surrounding the spacecraft on all sides. These should be located at the walls of the vacuum chamber since they will be conductive and should not interfere with the clear space around the satellite.

Less than full heat input from the solar simulator lessens the require-
ments on the cold wall. Some cold walls will always be needed for continuous
operation, however, since even heat dissipation in the spacecraft systems must
be radiated to prevent overheating. On the other hand, the cold-wall tempera-
ture and/or heat input to the spacecraft must be controllable to prevent the
spacecraft from freezing. In fact, emergency power for the spacecraft and
solar array needs to be provided, as well as an emergency procedure for dump-
ing the cold-wall refrigerant if that becomes necessary. Emergency power for
the vacuum pump is also required so that control of the vacuum can be maintained.
The cold wall should, therefore, be compatible with either liquid or gaseous
nitrogen (LN_2 or GN_2) so that a temperature higher than LN_2 temperature can be
maintained when required. If only LN_2 is used, the sun's heat input must be
simulated to prevent freezing of the spacecraft. Spacecraft use specific
heat-radiating areas that differ from spacecraft to spacecraft. This, combined
with the desirability of placing the spacecraft in arbitrary orientations,
means that the cold walls will have to surround the spacecraft and be individually
controllable. Control of the cold walls is required from the beginning of pump-
down until the end of venting. This is done by the spacecraft thermal people
who actually operate both the spacecraft and facility to keep the satellite
within design limits of temperature. Thermal equilibrium of the satellite
is absolutely required for operation and will be achieved 8 to 24 hours after
vacuum is achieved. A final thermal problem is the use of heat pipes in some
satellites. These will not operate properly in a one-gravity environment
unless the pipes are oriented exactly horizontally. This requirement would
limit exposure orientations of satellites where all of the pipes were in one
plane to the orientation that held that plane horizontal. If the pipes are
in more than one nonparallel plane, one or more sets of pipes would be nonfunc-
tional for all orientations. These are usually used to cool TWTA's, and the
result of nonfunctional heat pipes would be that the associated TWTA's could
not be operated. Alternate ways of cooling the TWTA's are possible (e.g.,
removing a thermal closeout), but these may change the electromagnetic charac-
teristics of the spacecraft.

Operating RF links in the vacuum tank with reflective walls will be a
problem. It appears that the TLM link will not be simple, but possible. The
principal consideration is SWR of the transmitter, which may require that some

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absorber be used around the antenna at the wall of the tank. But most manufacturers have operated TLM links in vacuum tanks, so this is a solvable problem. Operating transponders will be much more difficult, if not impossible. The usual way of testing transponders in vacuum tanks has been to replace the antenna with a dummy load and use a coupler to tap off a small amount of RF, which is carried to the transponder test set via coaxial cables. It may be possible to use this technique and substitute dielectric waveguide for the coaxial cable in the tank. But then SGEMP effects in the antenna would not be coupled to the spacecraft transmitters. A possible alternative, which has not been checked out with any of the manufacturers, is to use the setup in Figure A-2. Here a circulator has been added between the coupler and spacecraft antenna. This is placed so that RF power from the transmitter is absorbed by the termination, with very little of it reaching the antenna. Received signals from the antenna (including SGEMP-induced signals), however, reach the transmitter and receiver unattenuated.

To complete the simulation of a space environment, the sun and earth will have to be simulated either optically or electrically. Most, if not all, spacecraft have a test connector which is used during system checkout to put in stimuli to the spacecraft systems. This includes electrical simulation of earth and sun. The test connector could be used if a dielectric link, e.g., a fiber optics data link, were provided to interface the system test equipment to the spacecraft. Alternately, the sun ($1/2°$) and earth ($17°$) could be simulated optically. For a spinning spacecraft, which would be stationary, the "sun" and "earth" would have to be chopped so that the spacecraft thinks it is spinning. These simulations do not appear to be difficult. A photoflash has been said to be adequate for a sun simulator, while a hot plate (with a chopper, if required) is adequate for the earth. (For earth simulation, the principal consideration is the difference between the temperature of the earth simulator and background.)

A.5 INSTRUMENTATION AND DIAGNOSTICS

This area is divided into two distinct categories: instrumentation for the spacecraft systems and instrumentation for measuring the SGEMP response.
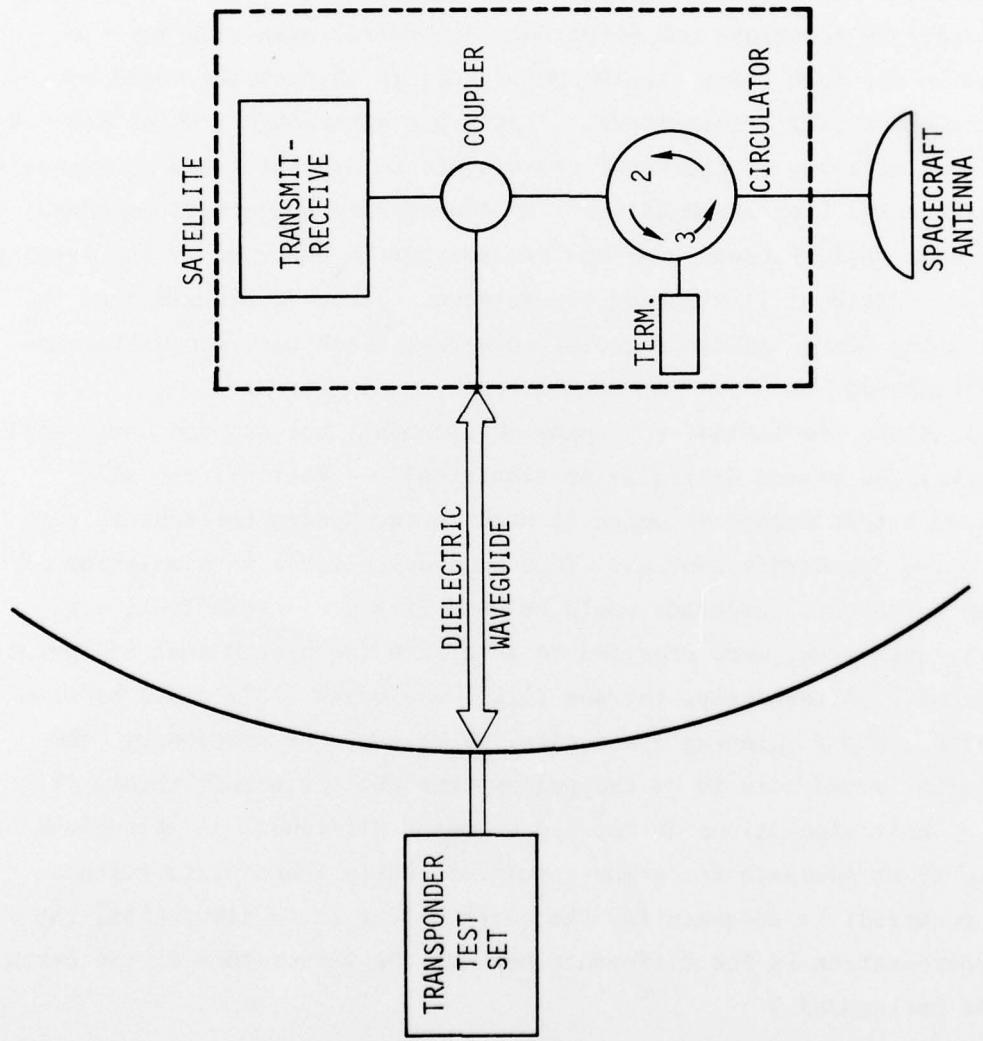
Figure A-2. Possible transponder test setup

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It appears that normal spacecraft TLM can provide all that is needed to diagnoise the health of the spacecraft before and after each exposure. TLM will also be able to detect transient upsets that result in changes of operating mode. Only one manufacturer has indicated a need to connect to the test connector in order to perform a complete system test (TRW on FLTSATCOM), and the exact reasons for this requirement are not known.

A complete TLM frame takes up to three minutes to obtain. Diagnosing failures in detail can take minutes to an hour using normal means, but special programs can probably be written to reduce the time to minutes. All manufacturers use minicomputers to operate their spacecraft, usually one to format commands and one for TLM processing with an interactive link between them, or else a single larger computer.

In addition to the TLM/command test equipment, a transponder test set is required to test communications satellites.

As far as instrumentation for measuring the SGEMP response of the satellite is concerned, there will never be enough to completely satisfy all desires. It would be desirable to measure enough surface currents, strut currents, and bulk cable and wire currents to completely characterize or verify the satellite SGEMP response. But there will be a limit on the amount of instrumentation that can be placed on the satellite without seriously disturbing its electromagnetic configuration. On the other hand, the great lengths of time required to configure the experiment, pumpdown, and test, and repressurize the tank (probably two or three days minimum) will probably preclude the possibility of using more than one or at most two different probe configurations. There will probably be a need to limit the number of exposures the satellite receives as well, especially for proto-flight or flight (e.g., solar panel) hardware. It is expected that a combination of approximately eight different operating modes will be required for each satellite, so a fairly large number of exposures is already required. The nature of the source must also be considered in the instrumentation. A very nonrepetitive source (i.e., one whose time history and spectrum change from shot to shot) makes it highly desirable to measure all of the responses on each shot. Thus, the trend should be to provide as many channels as possible for measuring the response.

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The data must, of course, be transmitted via a dielectric link, e.g., fiber optics. This further adds to the internal (to the satellite) instrumentation problem, since the device that converts each measured electric signal to the transmission medium will occupy a finite volume. Some satellites are already so tightly packed that the addition of even a single box would be a problem, although many have some open area which could be used. As a means of solving this space problem while minimizing upset of the electrical configuration, it is suggested that the data transmitters be placed in dummy load boxes that replace the redundant electronics boxes on the satellite. These redundant boxes are normally not present in prototype or qualification model satellites and must be simulated in some way to preserve the electrical characteristics of the satellite. They could have the same size and shape and present approximately the same electrical loads as the missing boxes, but their unused internal volume would be occupied with the data transmitters. This would greatly simplify the instrumentation problem, especially miniaturizing the data transmitters, i.e., there is more volume for them, so they need not be so small.

For the range of satellite types that may be tested, the following measurements would be desirable for characterizing the satellite response.

E Fields	3-6	E Probe
Surface H Field	8-12	$\dot{B}$ Probe
Strut Currents	4-6	Current Probe
Cable Currents	10-15	Current Probe

Thus, 25 to 40 channels of instrumentation are desirable. Resonances are expected to be as high as 150 to 200 MHz, which sets the upper limit of sensor and instrumentation frequency response. Responses are expected to ring out to 500 to 1000 nsec, which sets the lower limit on frequency response. Some sensor development will be required in the $\dot{B}$ and I-probe areas. Surface H field measurements will have to be made without cutting holes in the satellite. Thus, sensors need to be developed which can be mounted on the surface and taped in place with conductive tape. They also need to be radiation resistant and as

small as possible consistent with required sensitivity, which in turn is dependent on data link signal-to-noise ratio in the radiation environment. Current probes will need to have larger apertures than the currently used standard probes which have a 1.25-inch aperture. Struts and cable bundles may be up to three inches on real satellites, and clamp-on probes with apertures this large need to be developed. Strut and cable currents of the order of 100 to 1000 mA are expected, and major funnel point currents will be of the order of 10 amps at the fluence of interest.

The data link transmitters will be battery powered, and adequate battery life for a complete test sequence will be mandatory. Probably some means of turning them on and off remotely will be required.

A.6 SUPPORT REQUIREMENTS

The support requirements for the SXT facility consist basically of a satellite preparation/checkout area and a control room. The preparation area should be approximately 100 feet x 100 feet, with a high ceiling (>20 feet), and an overhead crane. This area must be fully environmentally controlled, including humidity, temperature, and cleanliness. The control room, where all of the AGE is located, should be approximately 20 feet x 40 feet adjacent to the preparation area (with windows between) and within 50 feet of the vacuum tank. Ten to twenty racks of equipment will be located in the control room, with 5 to 10 KVA of power required per rack, and about 20 tons of air conditioning to cool the room. Four desks will be required in the control room and a table long enough to lay out approximately 20 feet of chart paper.

The operating crew will be 5 to 10 people per test shift, with only a skeleton crew required when testing is not being conducted. Most satellite manufacturers expect to operate two and possibly three shifts, so that convenient living and eating facilities for 20 to 30 people will be required near the test facility.

Two desks must be provided in the chamber control room for the satellite thermal people, and a communications link between the satellite control room and the chamber control room.

Test equipment requirements will consist of scopes, meters, RF sources, and other normal test equipment. Any special or exotic test equipment will be supplied by the satellite manufacturer.

A.7 FACILITY REQUIREMENTS

The facility should contain the following:

1. Office space for the facility crew and professional staff.

2. A small electronics lab with an equipment crib to check out general-purpose test equipment (10 feet x 20 feet).

3. A small machine tool shop to fabricate small mechanical assemblies.

4. A truck-loading dock to unload the satellite shipping container.

5. A ramp or crane to move the shipping container to a staging area where the satellite may be uncrated. (The maximum shipping weight should be 4,000 pounds. This area should be relatively clean, approaching a level 100,000 clean room.)

The uncrating may be accomplished outside this area and the satellite immediately moved inside the clean area. Cranes should be tested or validated once each week or month (depending on usage) to certify their weight-carrying ability.

The satellite should then be moved into a test chamber, either side-loaded or top-loaded, and suspended or fixed in the test location. The satellite is then made ready for test by the traveling crew and the resident crew.

The test chamber should be kept clean, approaching 100,000 clean room standards. The chamber should be air conditioned by controlling temperature, humidity, and pollutants.

The test chamber should be sized to contain: (a) the flux generator; (b) the satellite to be tested (approximately a 40-foot linear dimension by 5 feet); and (c) a heat exchanger located along the walls of the test chamber. The heat exchanger or cold wall should be fabricated in sections in such a way that the temperature of selected areas can be controlled independently. The area size requires further study. The temperature should be controlled from room temperature to liquid nitrogen temperature with a minimum of thermal lag or inertia.

Control of the temperature may be accomplished by feedback from the satellite telemetry and the ground station personnel directing the facility control or by facility transducers placed on the satellite and transmitted to the control room via fiber-optic channels. The output from this system could control the cold wall automatically with human observers to override the system if a malfunction should arise.

The test chamber should also provide elevators to allow workmen to get sufficiently close to the satellite to perform maintenance, install transducers, and install instrumentation. The control of the elevators should be locally controlled with sufficient freedom to handle various sizes and shapes of satellites.

The test chamber should also have the capability for support of solar panels in the deployed configuration.

All satellite suspension systems should be equipped with readouts to show the loading on each suspension line displayed on meters with maximums not to be exceeded.

The facility needs a security system to shield the outside world from viewing secret satellites. The security should include electrical, electronic, audio, and visual security systems.

The facility also requires five major instrumentation or control systems:

1. Machine control

2. Machine diagnostics instrumentation

3. Facility control, temperature, altitude, humidity, and pressure

4. User instrumentation, including space for the user racks

5. Experimental racks.

Items should be housed in a shield room capable of excluding the harmful effects of the machine or radiation generator.

Items 1, 2, 4, and 5 could all be housed in one long shield room, with shielded partitions to separate each facility. Each partitioned room should have a door to the outside and a door to each adjacent room. The rooms should

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be constructed (from right to left) as follows: machine control, machine diagnostics or instrumentation, experimental room, and customer instrumentation. The single-room plan could also be divided into two shield rooms, machine control and diagnostics, and the experimental and customer instrumentation room.

The facility control room could also be enclosed in the machine control and diagnostics room, except that the added size would make it prohibitive. If the facility control room was not located in a shield room, the design would have to be done with care to eliminate high currents from the machine from entering and damaging the hardware.

The size of the user instrumentation room should accommodate 20 racks of equipment. The space may be occupied by displays, disk drives and racks, but the space requirements would be about the same. Additional space is required for desks and tables. Smaller accommodations could be realized if the TLM and control was done on telephone lines to the vendor facilities, where the majority of equipment would be located. A synch ronous satellite could also be the medium for transmitting telemetry and control signals. This would reduce the on-site space to a few racks, and the personnel complement required to two to four people. The expected size of this room is 10 feet by 20 feet.

The experimental shield room should contain the signal-conditioning and data-acquisition equipment for measurement of cable currents and other functions required to analyze the effects due to the irradiation.

Twelve to twenty-four transient digitizers and analog-to-digital converters should be used to measure these effects. Approximately 12 racks of equipment plus a desk and table should require a 10 foot by 15 foot room with access to the user instrumentation room.

The control room should contain the controls necessary to fire the machine and monitor the facility environment and security. This room should be an approximately 10 foot by 12 foot room.

The machine diagnostic room should contain the necessary instrumentation to analyze the operation of the machine and to measure the acceptance criteria when checked out by the machine manufacturer.

The spacecraft needs to be supplied with power during all phases of operation. During the irradiation period, the internal batteries of the spacecraft should be used so that electrical isolation can be maintained. This will

require a power changeover switch with a minimum of capacitance to the facility. The control of this power changeover switch can be by hardwire from the experimental data room or the user data room.

Other instrumentation for measurement of spacecraft phenomenon should be coupled to the data room by fiber optics to maximize electrical isolation between the spacecraft and the facility.

The spacecraft communications into the facility tank should be by dielectric waveguide for low-power systems. High-power transmission should be into a dummy load and sample the output through a dielectric waveguide.

Most test satellites are not equipped with a full array of solar cells, so testing would have to be accomplished using the existing cells and dummies for the remainder. To power the available cells, an incandescent source would be adequate.

The diagnostic software and the experimental data software should be variations of the software that was generated for the CASINO facility data room. CASINO is a flash x-ray facility at the Naval Special Weapons Laboratory (formerly the Naval Ordnance Laboratory). The diagnostic software was developed by IRT Corporation.

APPENDIX B

APPLICABLE DOCUMENTS (SCREEN ROOMS)

The following documents are selected to characterize and specify an enclosure for electromagnetic (RF) shielding.

MILITARY STANDARDS

MIL-STD-202A	Test Methods for Electronic and Electrical Components
MIL-STD-220A	Method of Insertion-Loss Measurement
MIL-STD-248	Qualification Tests for Welders (other than aircraft weldment)
MIL-STD-285	Attenuation Measurement for Enclosures, Electromagnetic Shielding, for Electrical Test Purposes, Method of

MILITARY SPECIFICATIONS

MIL-F-15733E(1) (Supplement 1)	Filters, Radio Interference

GOVERNMENT PUBLICATIONS

DCA CIR 300-175-1	DCA Red/Black Engineering Installation Criteria (U) with Changes 1, 2, and 3

FEDERAL SPECIFICATIONS

TT-P-645	Primer Paint, Zinc-Chromate, Alkyd Type

NAVAL ELECTRONICS COMMAND, SAN FRANCISCO BAY NAVAL SHIPYARD

RM 10A 751	Instruction Manual on the Use of a Shielded Enclosure Leak Detection System

NONGOVERNMENT DOCUMENTS

1. American Iron and Steel Institute, Light Gauge Cold-Formed Steel Design Manual

2. National Electrical Code, 1970 (NFPA)

3. NEMA Standard N-17, 1960

4. NEMA Standard SG-8.2, 1959, Pressure Connector for Copper Conductors, Screw-type

5. American Welding Society, Code for Welding in Building Construction

6. Raytheon Shielded Room Leak Detection System, Part No. 370708 Maintenance Manual and Operating Instructions

7. Uniform Building Code, 1970 edition.

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